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METEOROLOGY.—*A return to normal atmospheric transparency.* H. H. KIMBALL. Weather Bureau.

Attention has already been invited in this *Journal*, **3**, 269, to the diminution in atmospheric transparency which was quite generally observed during the latter part of 1912, and which was attributed, in part at least, to the presence at high levels of great quantities of dust derived from the eruption of Katmai Volcano in Alaska, in June, 1912. It will doubless be recalled that the first violent eruption occurred on June 6, that the dust cloud was first observed at Madison, Wis., on June 8, at Mount Weather, Va., on June 10, at various points in Europe between June 20 and June 27, and at Bassour, Algeria, on June 19.

The purpose of the present paper is to present evidence derived from observations made at the Mount Weather Observatory, or under its supervision, relative to the gradual precipitation of this dust from the atmosphere.

Humphreys[1] has computed that dust particles of the size that are thrown to the greatest heights by the most violent volcanic eruptions require from one to three years to fall to the under surface of the isothermal layer. From this level they will quickly be carried to the surface of the earth by the processes of condensation and precipitation of atmospheric moisture. These computations seem to be in accord with the duration of the various optical phenomena that have been observed to follow volcanic eruptions.

[1] Bull. Mount Weather Obs., **6**, 11, 1913.

The following observations are available for a study of the gradual precipitation of dust from the atmosphere during the past year:

1. Measurements of the intensity of insolation, or the incoming solar radiation.
2. Measurements of the percentage of polarization of skylight.
3. Measurements of the solar and the anti-solar distances of the neutral points of Babinet and Arago, respectively.
4. Observations of the intensity and duration of twilight colors.

*Solar radiation intensity measurements* have been made at frequent intervals thruout the day at Mount Weather since the beginning of 1908. But few observations were obtained in 1910, and in the winter months previous to 1912–1913.

For comparative purposes I have summarized in Table 1 the observations made since May 1, 1912, with the sun at zenith distance 60°, which is the highest point reached by the sun in December at the latitude of Mount Weather. The monthly means of measurements made in the successive years are not strictly comparable, for the reason that since May, 1911, the attempt has been made to obtain measurements whenever the sun was unobscured by clouds, while previous to that time measurements were made on the best days only, and when there was a prospect of obtaining a series extending over at least two hours.

The ratios in column 6, Table 1, are the means of the quotients obtained by dividing the monthly means, given in columns 2 and 3, by the corresponding averages for the respective months, derived from observations obtained previous to June, 1912.[2] Similarly, the ratios in column 7, Table 1, are the means of the quotients obtained by dividing the monthly maxima, given in columns 4 and 5, by the corresponding average maxima for the respective months, derived from observations obtained previous to June, 1912.

After what has been said relative to the monthly means for consecutive years we might expect that the ratios given in column 7, which are derived from maximum radiation values, would be

[2] These observations will be found tabulated in Bull. Mount Weather Obs., 5, 303–310, 1913.

larger than the ratios of column 6, which are derived from mean radiation values. Actually, however, the averages of columns 6 and 7 are practically in accord for 1912, omitting the ratios for May 1 to June 9, inclusive, while for 1913 the average of column 7 exceeds the average of column 6 by about 5 per cent.

TABLE 1

MONTHLY SUMMARY OF SOLAR RADIATION INTENSITIES WITH THE SUN AT ZENITH DISTANCE 60°. MOUNT WEATHER, VA.

| MONTH | MEAN | | MAXIMUM | | RATIO CURRENT AVERAGE | | MEAN RATIO |
|---|---|---|---|---|---|---|---|
| | a. m. | p. m. | a. m. | p. m. | | | |
| | Gram calories per min. per cm² | | | | mean | max. | |
| 1912 | | | | | | | |
| May 1–June 9 | 1.08 | 1.01 | 1.25 | 1.26 | 1.06 | 1.15 | 1.10 |
| June 10–30 | 0.90 | | 1.05 | 1.01 | 0.86 | 0.86 | 0.86 |
| July | 0.83 | 0.88 | 0.93 | 0.93 | 0.86 | 0.77 | 0.81 |
| August | 0.77 | | 0.86 | 0.75 | 0.73 | 0.70 | 0.71 |
| September | 0.89 | 0.94 | 1.05 | 0.97 | 0.80 | 0.81 | 0.81 |
| October | 1.03 | 0.97 | 1.22 | 1.24 | 0.81 | 0.91 | 0.86 |
| November | 1.14 | 1.12 | 1.24 | 1.17 | 0.90 | 0.88 | 0.89 |
| December | 1.26 | | 1.33 | | 0.97 | 1.01 | 0.99 |
| 1913 | | | | | | | |
| January | 1.21 | | 1.29 | 1.24 | 0.90 | 0.93 | 0.92 |
| February | 1.15 | 1.13 | 1.27 | 1.24 | 0.91 | 0.94 | 0.93 |
| March | 1.04 | 1.05 | 1.16 | 1.16 | 0.85 | 0.94 | 0.89 |
| April | 0.97 | 0.88 | 1.18 | 1.11 | 0.79 | 0.95 | 0.87 |
| May | 0.90 | 0.82 | 1.06 | 0.96 | 0.87 | 0.92 | 0.90 |
| June | 0.90 | 0.93 | 1.15 | 1.09 | 0.89 | 0.93 | 0.91 |
| July | 0.88 | 0.87 | 1.06 | 1.04 | 0.88 | 0.86 | 0.87 |
| August | 0.91 | 1.04 | 1.03 | 1.16 | 0.93 | 0.96 | 0.95 |
| September | 1.11 | 1.06 | 1.26 | 1.20 | 0.95 | 0.99 | 0.97 |
| October | 1.18 | 1.12 | 1.30 | 1.24 | 0.87 | 0.94 | 0.91 |
| November | 1.19 | 1.17 | 1.32 | 1.33 | 0.94 | 0.97 | 0.96 |
| December | 1.31 | | 1.42 | | 1.01 | 1.08 | 1.04 |

The last column of Table 1 is simply the average of the two preceding columns. It is believed that it gives a close approximation to the monthly means of the relative intensity of solar radiation for the period under consideration, as compared with the intensity under normal conditions for the respective months. These relative intensities, together with intensities for Madison,

Wis.,[2] obtained in a similar manner, are plotted in figure 1. The curve that best fits the data shows a rapid fall from above normal between May 1 and June 9, 1912, to 29 per cent below normal in August 1912, followed by a rapid rise during the autumn of 1912, and a slower rise in 1913 to normal values at the end of the year. So few radiation measurements have been obtained during winter months that the relative intensities computed for these months are of doubtful value. The intensities measured at Mount Weather on December 13, 1913, are as high as have ever been measured at this observatory with the sun below zenith distance 60°.

TABLE 2

TOTAL RADIATION RECEIVED ON A HORIZONTAL SURFACE FOR HOURS THAT WERE CLOUDLESS. RATIO $\frac{1912}{1913}$. MOUNT WEATHER, VA.

| PERIOD | HOUR ANGLE FROM NOON | | | | | | |
|---|---|---|---|---|---|---|---|
| | 7-6 6-7 | 6-5 5-6 | 5-4 4-5 | 4-3 3-4 | 3-2 2-3 | 2-1 1-2 | 1-0 0-1 |
| May 20–June 9 | 0.61 | 0.87 | 0.96 | 0.98 | 1.04 | | |
| June 10–July 31 | 1.04 | 1.00 | 1.05 | 1.02 | 0.94 | | |
| September 1–October 31 | | | 0.96 | 0.95 | 0.96 | 0.94 | 0.96 |

Measurements of the total radiation received on a horizontal surface from the sun and sky have been made at Mount Weather since May, 1912. A comparison of the results for 1912 and 1913 for hours when the sky was cloudless is given in Table 2. The results for August are omitted, as a different register was used in August, 1913 from that in operation during the other months.

There are not many hours during the summer, at Mount Weather, when the sky is free from clouds. It can therefore only be claimed that the data in Table 2 indicate that with a cloudless sky the total radiation received on a horizontal surface during September and October, 1912, was about 5 per cent less than that received during the same period in 1913, and that there was much less heat received diffusely from the sky between May 20 and June 9, 1912, than during the same period in 1913. This

[2] The observations for Madison, Wis., previous to July, 1912, will be found tabulated in Bull. Mount Weather, Obs., **5**, 177–181, 1912.

latter is indicated by the smallness of the ratios for early morning or late afternoon hours for the first period in Table 2. With low

TABLE 3

MONTHLY SUMMARY OF SKYLIGHT POLORIZATION IN THE SUN'S VERTICAL AND AT SOLAR DISTANCE 90°, WITH THE SUN AT ZENITH DISTANCE 60°, MOUNT WEATHER, VA.

| | PERCENTAGE OF POLARIZATION | | | | | | DEPARTURE FROM AVERAGE | |
|---|---|---|---|---|---|---|---|---|
| | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1912 | 1913 |
| January | | | | | | | | |
| Mean | 58 | | 69 | | | 52 | | −12 |
| Maximum | 65 | | 69 | | | 57 | | −10 |
| February | | | | | | | | |
| Mean | 53 | | 71 | | | 46 | | −16 |
| Maximum | 54 | | 71 | | | 53 | | − 9 |
| March | | | | | | | | |
| Mean | 57 | | 67 | | | 44 | | −18 |
| Maximum | 61 | | 69 | | | 50 | | −15 |
| April | | | | | | | | |
| Mean | 62 | 62 | | | | 42 | | −20 |
| Maximum | 64 | 62 | | | | 49 | | −14 |
| May | | | | | | | | |
| Mean | 58 | 64 | | 48 | 54 | 41 | − 2 | −15 |
| Maximum | 61 | 65 | | 56 | 65 | 50 | + 4 | −11 |
| June | | | | | | | | |
| Mean | 59 | | | 61 | 42 | 44 | −18 | −16 |
| Maximum | 64 | | | 70 | 53 | 50 | −14 | −17 |
| July | | | | | | | | |
| Mean | 62 | | | 55 | 39 | 44 | −19 | −14 |
| Maximum | 70 | | | 71 | 47 | 54 | −23 | −16 |
| August | | | | | | | | |
| Mean | 61 | 56 | | 59 | 32 | 49 | −27 | −10 |
| Maximum | 63 | 67 | | 69 | 40 | 58 | −26 | − 8 |
| September | | | | | | | | |
| Mean | 65 | 64 | | 60 | 40 | 56 | −23 | − 7 |
| Maximum | 69 | 67 | | 70 | 44 | 63 | −25 | − 6 |
| October | | | | | | | | |
| Mean | 66 | 70 | | 69 | 44 | 57 | −24 | − 4 |
| Maximum | 71 | 71 | | 75 | 51 | 63 | −21 | − 9 |
| November | | | | | | | | |
| Mean | 62 | | | | 47 | 58 | −15 | − 4 |
| Maximum | 62 | | | | 53 | 66 | − 9 | + 4 |
| December | | | | | | | | |
| Mean | 68 | | | | 52 | 59 | −16 | − 6 |
| Maximum | 70 | | | | 61 | 66 | − 9 | − 4 |

sun, the proportion of the radiation that is received diffusely from the sky is relatively great.

*Skylight polarization* is intimately connected with atmospheric transparency, since an increase in the primary diffusion is accompanied by an increase in the secondary scattering in the lower atmosphere. This increases the intensity of the horizontally or negatively polarized component of the light, and neutralizes to some extent the postive or vertical polarization of skylight. In Table 3 are summarized skylight polarization observations made

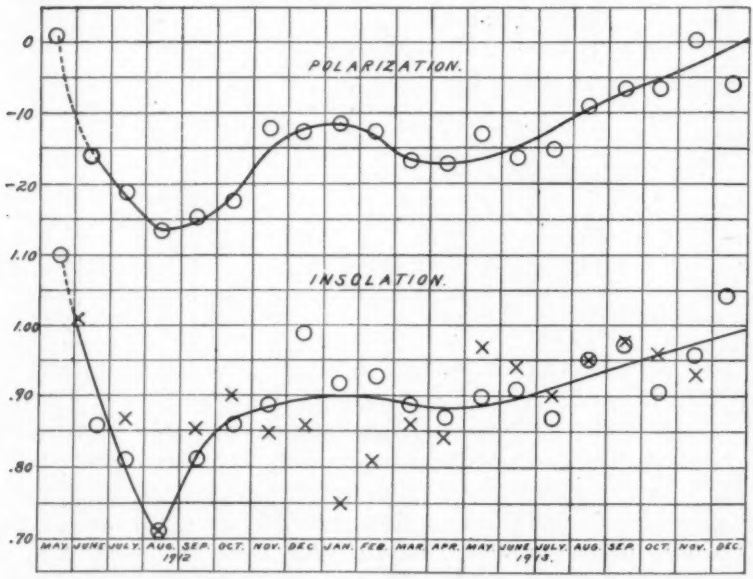


Fig. 1. Variations in solar radiation intensities and in the percentage of skylight polarization. Circles indicate data for Mount Weather, Va.; crosses, data for Madison, Wis.

at Mount Weather when the sky was free from clouds and there was no snow on the ground. In the last two columns are given the departures of the monthly values for 1912 and 1913 from the averages for the respective months derived from observations taken previous to June, 1912. These departures are plotted in

figure 1, and their variations are in close accord with the variations in the relative intensity of solar radiation.

TABLE 4

ANTISOLAR DISTANCE OF ARAGO'S NEUTRAL POINT. MOUNT WEATHER, VA.

| ALTITUDE OF SUN | DATE OF OBSERVATIONS | | | | |
|---|---|---|---|---|---|
| | May, 1911–June, 1912 | July 27, 1912 | September, 1912–June, 1913 | August–November, 1913 | December, 1913 |
| *degrees* | *degrees* | *degrees* | *degrees* | *degrees* | |
| +13.0 | | | 25.8 | | |
| 12.0 | | | 26.1 | | |
| 11.0 | | | 26.8 | | |
| 10.0 | | | 26.7 | | |
| 9.0 | | | 27.0 | | |
| 8.0 | | | | 23.7 | |
| 7.5 | | | 24.6 | 24.0 | |
| 7.0 | | | 25.3 | 23.4 | |
| 6.5 | | | 25.8 | 23.4 | |
| 6.0 | 19.7 | | 25.8 | 23.4 | |
| 5.5 | 20.3 | | 26.4 | 23.2 | 23.2 |
| 5.0 | 20.1 | | 25.7 | 23.3 | 23.3 |
| 4.5 | 20.1 | | 25.6 | 23.3 | 23.3 |
| 4.0 | 19.5 | | 25.8 | 23.3 | 23.2 |
| 3.5 | 18.8 | | 25.4 | 23.2 | 23.1 |
| 3.0 | 18.7 | | 25.4 | 23.4 | 22.9 |
| 2.5 | 18.5 | | 25.1 | 23.0 | 23.0 |
| 2.0 | 18.6 | | 24.6 | 22.8 | 22.7 |
| 1.5 | 18.6 | 21.7 | 23.8 | 22.5 | 22.8 |
| 1.0 | 18.4 | 21.7 | 23.3 | 22.2 | 22.4 |
| +0.5 | 18.3 | 19.8 | 22.2 | 21.7 | 22.0 |
| ±0.0 | 17.8 | 18.6 | 21.1 | 20.9 | 21.6 |
| −0.5 | 17.8 | 16.5 | 19.5 | 20.2 | 21.5 |
| −1.0 | 17.8 | 14.8 | 18.0 | **19.4** | 20.8 |
| −1.5 | 17.0 | 14.5 | 17.0 | 19.5 | **19.7** |
| −2.0 | **16.3** | 14.1 | 17.1 | 20.2 | 20.4 |
| −2.5 | 16.3 | 13.7 | 17.0 | 20.7 | 20.8 |
| −3.0 | 17.4 | **13.6** | 16.7 | 21.0 | 20.5 |
| −3.5 | 17.5 | 13.8 | **16.5** | 20.9 | 21.1 |
| −4.0 | | 14.8 | 17.6 | 20.8 | 21.0 |
| −4.5 | | 15.5 | 18.7 | 20.8 | 21.2 |
| −5.0 | | 18.1 | 18.9 | 21.5 | |
| −5.5 | | | 20.6 | 22.8 | |
| −6.0 | | | | 23.5 | |
| −6.5 | | | | 23.6 | |

During the early part of 1913, it was noticed that after sunset, as the lower atmosphere became less and less illuminated, the skylight polarization increased rapidly, sometimes by as much as 50 per cent, and to nearly the degree of polarization under normal conditions. This increase became noticeably less after the middle of August, 1913.[4]

*The solar and the antisolar distances of the neutral points of Babinet and Arago*, respectively, have varied in accordance with the variations in skylight polarization. This was to be expected, since these distances depend upon the relative intensities of the vertically and the horizontally polarized components of skylight.

Table 4 will serve to illustrate the movements of both the neutral points. It will be noticed that simultaniously with the increase in the diffusion of light by the dust in the upper atmosphere, there was an increase in the antisolar distance of Arago's neutral point with the sun above the horizon. With the sun below the horizon, however, the intensity of the primary-diffused light from the upper atmosphere, which was highly but not necessarily completely polarized, caused a decrease in the antisolar distance of this neutral point. The minimum distance was not only smaller, but it occurred with a lower sun than under normal conditions.

With the decrease in the intensity of the primary-diffused sunlight, in 1913, the antisolar distance of the neutral point gradually increased with the sun below the horizon, and the minimum distance occurred with a higher sun.

Jensen[5] has shown that there may be a relation between variations in the color of skylight and the positions of the neutral points.

At the present time the solar and the antisolar distances of the neutral points appear to be decreasing with the sun both above and below the horizon.

[4] Skylight polarization measurements made after sunset will be found tabulated in Bull. Mount Weather Observatory, **6**, 39, 1913.

[5] Jensen, Dr. Chr., Über die grosse atmospherisch-optische Störung von 1912, pp. 10–11 (Separatabdruck aus den Mitteilungen der Vereinigung von Freunden der Astronomie und kosmischen Physik).

*The twilight colors* are intensified by the presence of fine dust in the atmosphere, as was markedly the case after the eruption of Krakatoa Volcano in 1883. In another paper[6] I have presented evidence that during the fall of 1912 the red colors, especially, were unusually brilliant, and perhaps, also, of unusual duration. At the Mount Weather Observatory the brilliancy of the twilight colors has been the occasion of frequent remark during the past few months, and especially during September, October, and November. On some evenings the glow in the west has been distinguishable for nearly an hour and a half after sunset.

During the fall of 1912 a noticeable feature of twilights was the streaked appearance of the sky, as tho the dust or haze was arranged in horizontal layers. This has not been the case during the fall of 1913.

Notes relative to twilight colors made by Weather Bureau Observers at the various stations thruout the United States are rather inconclusive as to the intensity of these colors in 1913 as compared with their intensity in 1912. It seems evident, however, that while the maximum of intensity culminated in the month of November, in 1912, in 1913 the maximum was reached as early as September.

*Summary.* Pyrheliometric and polarimetric observations unite in indicating a gradual increase in atmospheric transparency since the marked minimum in August, 1912. This increase is probably due to the precipitation from the atmosphere of the dust that was introduced into high levels by the eruption of Katmai Volcano in June, 1912.

At the same time, the solar and the anti-solar distances of the neutral points of Babinet and Arago respectively, indicate that there may still be traces of this dust in the upper atmosphere.

The duration of the Katmai dust cloud appears to have been less than the duration (2 years) of the dust cloud that followed the eruptions of 1902–03, and markedly less than the duration (3 years) of the dust cloud that followed the eruption of Krakotoa in 1883.

[6] Monthly Weather Review, **41**, 153–159, 1913.

GEOLOGY.—*Sketch of the geologic history of the Florida coral reef tract and comparisons with other coral reef areas.*[1] THOMAS WAYLAND VAUGHAN, U. S. Geological Survey.

## GEOLOGIC FORMATIONS OF SOUTHERN FLORIDA

The southern end of the mainland of Florida is underlain by two limestone formations, viz: the somewhat sandy, rather soft, light colored Miami oolite, and the more or less sandy, non-oolitic, dark or light Lostmans River limestone, which may be friable or indurated, and sometimes is crystalline. Four principal kinds of material are represented in the Florida keys. The surface of the keys north of Cape Florida is sandy. The most conspicuous constituent of the main keys from Soldiers Key to the southern end of Big Pine Key is the Key Largo limestone, an elevated coral reef rock. The prevalent rock from the Pine Keys westward to Boca Grande Key is the soft, non-arenaceous Key West oolite. The surface material of the Marquesas is largely composed of the detrital remains of calcareous algae probably overlying an oolitic foundation, while that of the Tortugas is largely coral detritus underlain by more consolidated limestone.

In order to indicate the relative importance of oolite and the elevated coral reef rock in the formation of the keys and nearby parts of the mainland, the following rough planimeter measurements are given: Miami oolite, area 1300 square miles; Key West oolite, area 370 square miles—oolite, total area 1670 square miles. Key Largo limestone, elevated coral reef, area 66 square miles. According to these measurements chemical precipitation of calcium carbonate with subsequent transformation into oolite has predominated over the constructive agency of corals in the ratio of roughly 25: 1, but, as undoubtedly the figures for the oolite are too small and those for the elevated coral reef are too large, 100 : 1 is probably nearer to the proper ratio. In this connection it will be stated that on Andros Island, Bahamas, the ratio of the constructive work of the present reef to that of the agencies that previously resulted in the formation of the Pleisto-

[1] Published by permission of the Director of the U. S. Geological Survey and of the President of the Carnegie Institution of Washington.

cene oolite, is approximately as 1 to several thousand, or, as a constructive agent, chemical precipitation has been several thousand times more effective in forming limestone than corals.

### TOPOGRAPHIC RELATIONS OF THE FLORIDA BARRIER REEF

The living barrier reef of Florida extends as a broken chain from Fowey Rocks at the north to off Key West near Sand Key at its southwest end. Luxuriant reefs also occur around the Tortugas atoll. The principal reefs lie just within the 10-fathom curve and stand on the seaward margin of a platform. They are separated from the main line of keys by Hawk Channel, which has a maximum depth of about 7 fathoms, and the keys in their turn are separated from the mainland by a series of shallow bays and sounds. The platform on which the reefs stand extends around the entire coast of Florida. Northward of Fowey Rocks the reefs disappear but the platform continues. The platform also exists on the west side of the peninsula of Florida but bears no reefs. It is evident that the platform is independent of corals and that it owes its existence to agencies other than those dependent upon the presence of coral reefs.

### BUILDING OF THE MARQUESAS AND THE TORTUGAS

There are two rival hypotheses for the formation of atolls, one of these attributes them to the submarine solution of the interior of a mass of limestone; the other accounts for them by constructional agencies. In order thoroly to test the solution hypothesis the results of four lines of invetigations were brought to bear upon it, and all are concordant. (1) All the bays, sounds, and lagoons within the Florida reef and key region are filling with sediment; (2) Drew's investigations of denitrifying bacteria show that chemical precipitation of calcium carbonate is taking place in the lagoons; (3) the chemical examination by R. B. Dole of samples of sea-water flowing into and out of the Tortugas lagoon, collected twice daily for a lunar period, show that altho both carbonate and bicarbonate radicles are in solution uncombined carbon dioxide is not present, and that the water possesses no capacity for further solution of calcium carbonate

by virtue of its content of free carbon dioxide; (4) the determinations by Dole of the salinity of the water within the Tortugas lagoon and at the southern end of Biscayne Bay show a higher concentration than that in the open sea-water on the outside, indicating that tidal inflow and outflow are not sufficient completely to mix the water in the lagoons with the water of the surrounding sea and that concentration by evaporation is taking place. As the results of these lines of inquiry are so positive, the formation of lagoons by submarine solution may be definitely eliminated from consideration.

Of the constructional agencies to which the rims of atolls might be attributed attention was directed to the effects of winds and currents. It is a matter of common knowledge that if a current impinges against an obstruction lying across its course it divides, a part swerves to each side and incurves on the back of the obstruction, with the result that crescentic accumulations are built whenever the moving medium deposits material. It is also well known that the form of a deposit from a current moving in a straight line is correspondingly rectilinear. Current-shaped crescentic keys and crescentic sand dunes are familiar phenomena; as also are linear ridges formed either of water-borne sediment or of wind-driven sand. Good instances of crescentic keys and a mud atoll (Breton Island) are found off the mouth of Mississippi River.

As regards coral reefs, Hedley and Taylor have pointed out that, for the Great Barrier Reef of Australia:

> The growth of an individual reef is shown to proceed in a regular cycle. If the reef reaches the surface with its axis along the wind, then its shape endures; but if across the wind, then its extremities are produced backward, forming first a crescent, later a horseshoe, and lastly an oval, thus inclosing a lagoon.

There is a striking similarity in the configuration of the Marquesas and the Tortugas. There is an entrance to the lagoon of each in the southeast, southwest, and northeast quadrants; and the principal arc of the rim of each is from the southeast to the northwest entrance. The bow of this arc in each instance is against the prevailing direction of the wind, which is predominantly from the east, and against the direction of movement of

the Florida counter-current, while its northern limb in each instance trails with these currents. As many details of the Marquesas and the Tortugas can not be considered in this summary, the conclusion will at once be expressed that the atoll rims of both the Marquesas and the Tortugas are constructional phenomena and owe their configuration to the prevailing winds and currents. The detrital material on which these agencies have worked in the Marquesas is mostly of other than coral origin; while in the Tortugas, altho of complex composition, it consists largely of coral débris.

The Marquesas rim is geologically Recent, and evidently required no change of sea level for its formation. As the surficial material of the Tortugas rests upon an older, harder, calcareous basement, it appears that the Tortugas atoll with its inclosed lagoon was outlined during a previous physiographic cycle. Further evidence, later to be adduced, renders it reasonably certain that the Tortugas were initially outlined during subsidence after uplift following the close of the Pliocene, that they were then elevated to an amount of perhaps 50 feet, that the last event has been one of subsidence back nearly to the same level as that preceding the elevation, and that the Recent corals have established themselves on an old atoll basement already prepared for them.

## OSCILLATIONS OF THE FLORIDA REEF TRACT

A study of the Florida coast line shows that its last important movement was downward. This deduction is based on the existence of submerged channels and submarine fresh-water springs on the east coast, on the indented character of the coast line with accompanying submerged channels on the west coast, and on the presence of underground passages containing salt water and free openings or cavities that extend to a depth as great as 30 feet below sea level on the southern keys. The evidence is clear that the keys participated in the uplift and subsequent depression that affected the mainland, and that at one time they stood more than 30 feet higher with reference to sea level than they now do. This uplift and the subsequent depression, according to all available evidence, extended to the Tortugas.

The evidence presented shows that the platform on which the present barrier reef of Florida is growing has, geologically just antecedent to its present relation to sea level, stood 30 feet or more higher, and has been brought to its present position by depression.

The Pleistocene barrier reef, which is 105 feet thick according to the boring on Key Vaca, was formed during the period of subsidence which followed uplift at the close of Pliocene deposition.

### SUMMARY OF THE GEOLOGIC HISTORY OF THE FLORIDA REEF TRACT

The geologic history of the Florida reef tract may be summarized as follows: During Pleistocene time along a curve from the eastern side of Biscayne Bay, first trending southward and then bending westward, a barrier coral reef flourished. This was separated by a channel from the main bank on which the Miami oolite was forming or had formed in strongly agitated waters. West of the coral reef, on an extensive flat in shallow water, the Key West oolite was forming, while still farther westward the Tortugas were outlined under the influence of winds and currents. This period of events was succeeded by elevation of the entire key region to probably 50 feet above its previous level. The last period of uplift was succeeded by one of depression, lowering the surface 30 feet or more and establishing practically the same relation of the sea level to land as now prevails. Subsequent to the beginning of this depression the present barrier reef has developed seaward of the keys on a platform already prepared for it, the Marquesas have been formed by winds and currents, and coral reefs have again established themselves in the Tortugas.

### COMPARISONS OF THE FLORIDA REEF TRACT WITH THOSE OF ANDROS ISLAND, BAHAMAS, CUBA AND AUSTRALIA

Hayes, Vaughan, and Spencer showed in 1902, as is evidenced by the pouch-shaped harbors of the Cuban coast and by the submerged filled channels, such as the one in Havana harbor, that the last movement of the Cuban coast was downward. Therefore, the platform on which the Cuban reefs occur has

been brought to its present position by subsidence. The barrier reef of Andros Island, Bahamas, also occupies the outer edge of a depressed platform.

It has been shown by the Australians, Andrews, Hedley and Taylor, and David, that the platform of the Great Barrier Reef of Australia has been brought to its present position thru subsidence apparently associated with extensive faulting along the eastern Queensland coast. Therefore the Floridian, Cuban, Bahaman, and Australian barrier reefs all have a similar relation to change of sea level, as in each instance the platforms on which they occur have been brought to their present position thru subsidence.

There is one important difference between the relations of the Recent barrier reefs of Florida and Andros Island, Bahamas, and those of Cuba. The oscillations of the strand line in Florida and Andros Island have taken place without appreciable differential crustal movement, while in Cuba there was notable deformation antecedent to the last depression. The Pleistocene terraces rise in height toward the eastern end of Cuba in Oriente Province where altitudes of about 600 feet are attained near Cape Maisí. The terraces decline in height toward the west, and west of the longitude of Manzanillo there is a slope from the north to the south coast. In Barbados Pleistocene reefs extend to 1000 feet in elevation.

### COMPARISON OF WEST INDIAN WITH CENTRAL PACIFIC REEFS

Alexander Agassiz discovered that in the Paumotuan atolls the Recent corals were growing as a thin crust on an older limestone foundation. His explanation of the formation of the atolls by the destruction of the interior of a limestone mass must be discarded. As there was evidently a period of atoll formation in the Paumotus previous to the establishment of the Recent corals the conditions there simulate those in the Tortugas, Florida. A great developnent of Pleistocene and perhaps late Tertiary coral reefs in the tropical Pacific has been proven in the most convincing manner, and there is abundant evidence of differential crustal movement in the tropical Pacific in Pleistocene time similar

to that indicated for the West Indies. E. C. Andrews and C. Elschner have both described warping and tilting, the former for the Fijis, the latter for the Pacific more or less in general. Agassiz described an elevated atoll Makatea, in the Paumotus; and Andrews has given a detailed description of the elevated atoll of Mango, Fijis. Because of the differential nature of the earth movements, in certain places old atolls have been uplifted to heights as great as 230 feet in Makatea, and 600 feet in Tuvuthá, Fijis; while other old atolls, such as Rangiroa and others in the Paumotus, now stand at or near sea level. In other areas there has been depression, Bora Bora for instance, as Dana, P. Marshall, and more recently W. M. Davis, have shown. Systematic, detailed studies of the relations of the Recent to the older reefs, with special reference to oscillation of sea level and differential crustal movement in Pleistocene time, are among the desiderata in the investigation of coral reefs.

### BARRIER REEF PLATFORMS

It has already been stated that the existence of the platform on which the Recent barrier reef of Florida stands is independent of the reefs, as it is continuous irrespective of the geographic limits of the reefs. A similar statement may be made regarding the Bahamas and Cuba, where in each instance the platform is independent of the reefs which merely grow upon its surface where conditions are favorable for the life of corals. E. C. Andrews in 1902 remarked regarding the platform of the Great Barrier Reef of Australia that "the continuance in width of the shelf southwards of the limits of reefs (coralline), and the great shoals thereon, points to a minor part only of the shelf being formed of coral growth." An inspection of the Admiralty charts for the eastern coast of Australia shows conclusively that the platform on which the Great Barrier Reef of Australia stands has an existence independent of the Great Barrier Reef, and that corals have established themselves on this platform where the conditions favorable for their life are realized.

An examination of the barrier reef platforms of Florida, Andros Island, Bahamas, Cuba, and Australia, all lead to the same

conclusion, viz: (1) The platforms have an existence independent of coral reefs and were formed by other than coral reef agencies; (2) the reefs exist only on those portions of the platforms where the conditions requisite for the life of reef corals prevail.

In this connection attention is especially directed to the persistence along the margin of continental plateaus of a rapid declivity from about the 30-fathom curve to the 50-fathom curve as compared with the usually gentler slope from the shore to between 30 and 40 fathoms. This relation is well exhibited along both the Australian and the North American platforms.

Having presented criteria for recognizing the relations of continental and large insular platforms supporting barrier reefs to the presence of the reefs, islands such as those in the Society and Fiji groups may be considered. Daly in 1910 pointed out that the depth of the drowned valleys in these groups "appears never to exceed 45 fathoms." The maximum depth according to his compilation is from 19 (Raiatea) to 41 fathoms (Murea), both members of the Society group. There is wonderful accordance between the maximum depths within the barriers of the Pacific Islands and the depths on the Australian continental shelf both within and without the Great Barrier Reef region. A study of the charts of barrier reef islands, as Viti Levu, Fijis, and Tahiti, Society Island, shows that the platforms are independent of the presence of reefs, and therefore the relations in these islands are similar to those indicated for barriers off continental shores, for here the reefs are also superimposed on platforms antedating their presence. The problem of the depth of barrier platforms is a world-wide one for it is only an aspect of the general problem of the history of continental shelves.

## ATOLLS

The atolls previously discussed in this paper occur on platforms, rise from comparatively shallow depths, and owe their shapes to winds and currents. The atolls that margin flat summits of eminences rising from oceanic depth must be attributed to somewhat different causes. The greater abundance and luxuriance of reef-forming organisms on the peripheries of atolls are

due mostly, if not solely, to the intolerance of such organisms to sediment. Certain of my experiments show conclusively that, if the colonies are protected from sediment, the growth of corals within a lagoon may exceed that of corals on the outside. The possibilities of a basement attaining the proper depth, where the other necessary vital conditions prevail, are numerous and need not here be recapitulated.

As bearing on the relative stability of one so-called coral island, it will be stated that Dr. Jos. A. Cushman has found *Nummulites* in the borings from the Bermuda deep well at depths from 131 to 193 feet, or, expressed in fathoms, from 22 to 32 fathoms below sea level. As these fossils indicate either a lower Oligocene or an upper Eocene age for that part of the bore, it is evident that crustal changes in the Bermudas since that time have been slight. Relative crustal stability for the Paumotus has been indicated. Daly's compilation of the depth of atoll lagoons is most significant, as it shows accordance in depth with the lagoons of barrier islands. Whether or no his hypothesis of the rise of sea level to an amount of about 30 fathoms in the tropics, due to the disappearance of glaciers, be accepted, it at least is evident that great crustal subsidence for atoll areas is not indicated by the facts at present available.[2]

[2] This paper is an abstract of data and conclusions bearing on the coral reef problem from the following publications by the writer:

A contribution to the geologic history of the Floridian Plateau. Carnegie Institution of Washington, Publication 133, 99–185, 15 pls., December, 1910.

Remarks on the geology of the Bahama Islands and on the formation of the Floridian and Bahaman oolites (abstract). Jour. Washington Acad. Sci., **3**, 302, 303, May 19, 1913.

Preliminary remarks on the geology of the Bahamas, with special reference to the origin of the Bahaman and Floridian oolites. Carnegie Institution of Washington, Publication 182, 47–53, 1914 (in press).

The building of the Marquesas and Tortugas atolls, and a sketch of the geologic history of the Florida reef tract. Idem, 55–67, 1914 (in press).

To the abstract of discussions included in the papers cited are added a more general account of barrier reef platforms and some remarks on atoll rims that margin the flat summits of eminences rising from oceanic depths.

# PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

## THE BOTANICAL SOCIETY OF WASHINGTON

The 92d regular meeting of the Botanical Society was held at the Powhatan Hotel on Tuesday evening, December 2, 1913, at which a dinner and special program were given in honor of the seventieth birthday of Dr. Edward Lee Greene.

Dr. C. L. Shear presided. Mr. John H. Parker was elected to membership. The program was as follows:

*Personal experiences:* FREDERICK V. COVILLE. Mr. Coville related incidents in connection with his first meeting with Dr. Greene at the Madison Botanical Congress in 1893, and expressed a high appreciation of his work, particularly of his *Landmarks of Botanical History.*

*Berkeleyan days:* V. K. CHESTNUT. Mr. Chestnut spoke of his student days at the University of California and of the inspiration received from Dr. Greene by his botanical students.

*Botanical writings:* A. S. HITCHCOCK. As a writer, Dr. Greene has been prolific. Besides numerous papers in various periodicals, such as the bulletins and the proceedings of the California Academy, *Botanical Gazette, Bulletin of the Torrey Club* and *Erythea,* he has published several books, notably *Flora Franciscana, Manual of the Botany of the Region of San Francisco Bay,* five volumes of *Pittonia* and two volumes of *Leaflets.*

The value of Dr. Greene's influence upon botanical thought does not rest solely upon the large number of new species he has described, but in that he has studied many groups of plants from Cruciferae to Compositae, from Viola, Rhus and Eschscholtzia to Boraginaceae and Polemoniaceae, has revised many genera, sections and groups, discussed relationships, and set on their feet, as it were, species and genera of early authors that had been relegated to oblivion by those that followed.

*Reminiscences:* IVAR TIDESTROM. Mr. Tidestrom gave a brief account of Dr. Greene's earlier work, particularly his early collecting and his work at Berkeley.

*Rocky Mountain flora:* Prof. AVEN NELSON. Dr. Greene's work in the Rocky Mountain states was reviewed briefly and special emphasis was laid on the influence of this work on that of the later botanists.

*Response:* Dr. GREENE. After expressing his appreciation of the honor accorded him by the Botanical Society, Dr. Greene related a few interesting incidents connected with his life, particularly his early trips of botanical exploration in the Southwest.

P. L. RICKER, *Corresponding Secretary.*

## THE CHEMICAL SOCIETY

The 232d meeting was held at the Cosmos Club on December 11, 1913. Dr. M. X. Sullivan was nominated to represent the Society as a vice-president of the Washington Academy of Sciences. The president appointed A. B. Adams, J. A. Le Clerc, and R. C. Wells as an auditing committee to audit the accounts of the treasurer for the year.

The following papers were then read:

J. G. FAIRCHILD, of the Bureau of Mines: First paper: *Electroanalysis of the copper alloys.* The methods described were planned in order to obtain more rapid results in analyzing brass, bronze, type metal and other copper alloys. The paper has been published in *Met. and Chem. Eng.*

Second paper: *The iodometric determination of iron.* This paper, like the preceding, gave details of procedure for a rapid commercial method.

Discussion: Andrews pointed out that the reaction used in the method for iron comes to an equilibrium, which can be displaced toward ferrous iron by extracting the iodine with a solvent such as carbon bisulfide.

W. D. COLLINS, of the Bureau of Chemistry: *Radioactivity of Virginia mineral waters.* The tests were made by boiling out the gases from the sample and observing their effect on an electroscope. Activities of from 110 down to 0.7, in terms of the $10^{-11}$ unit, were found. These are of the same order of magnitude as radioactive springs in other parts of the world.

Discussion: Ross called attention to investigations published in the french *Comptes Rendus* showing that certain Italian springs caused, rather than cured, certain diseases. He showed that quantities of radium emanation that can be taken without effect greatly exceed the amounts that can be obtained from any spring water. Custis stated that experiments show that repeated small doses of the emanation produce effects that cannot be obtained by single large doses. I. K. Phelps mentioned that practically all waters are radioactive, but Collins pointed out that the activity of sea-water, for instance, is only about 0.001 of that of the least active of the springs in question.

G. A. MENGE, of the Hygienic Laboratory: *The Preparation of aminonitriles.* The speaker described the methods for preparing nitriles, going from anhydrous hydrocyanic acid thru cyanhydrin by means of liquid ammonia, as the methods described in the literature did not give satisfactory results. Amino-aceto-nitrile and a number of other members of this series were prepared. The liquid ammonia method gives practically the theoretical yield.

G. B. SPENCER, of the Bureau of Chemistry: *Goettingen.* The speaker first paid a tribute to Wallach, who has recently received the Nobel prize for his work on the terpenes. He then described the city and the university, and spoke in particular of the many important discoveries which the sciences of chemistry, physics, and mathematics owe to the men of Goettingen.

ROBERT B. SOSMAN, *Secretary.*

# VAMPIRES

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